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Soil Temperature Variations on a Semidesert Habitat in Southern Arizona

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Daily minimum soil temperatures were lowest at the surface and increased with depth; daily maximum soil temperatures were highest at the surface and decreased with depth. Diurnal variation was greatest (as much as 75° F.) at the surface and lowest (1° or 2° F.) at the 24-inch depth. Soil temperatures at the 3-, 12-, and 24-inch depths ranged mostly between 40° and 60° F. during the winter months, and between 70° and 90° F. during the summer months. Absolute maximum and minimum temperatures recorded were 141° and 29° F.

Soil temperature affects biological, chemical, and physical processes, including the rate of absorption of water and solutes, the germination of seeds, the rate of growth of roots, the geographic range of plant species, and the activities of microorganisms.² Thus, the temperature regime of the soil is an important dimension of the habitat. Soil temperature data collected from July 1961 to October 1963 on the Santa Rita Experimental Range, south of Tucson, Arizona, are presented here to characterize the soil temperature regime of this semidesert rangeland area.

Methods

The Study Area

The study area is in a semidesert grass-shrub type on a gently sloping northwest ex-

posure at an elevation of about 3,900 feet. Annual precipitation averages 13.67 inches, with about 60 percent falling between July and September. The vegetation consists of rather sparse stands of annual grass, perennial grass, and burroweed, Haplopappus tenuisectus (Greene) Blake, (a half-shrub) in various combinations, with considerable exposed soil (fig. 1). The soil is a sandy loam of the Continental series, with sand varying from 75 percent in the 0- to 6-inch layer to 64 percent in the 12- to 18-inch layer, and clay varying from 8 percent in the 0- to 6-inch layer to 16 percent in the 12- to 18-inch layer. Bulk density is 1.64 gm/cm³.

¹Range Scientist, located at Tucson, in cooperation with the University of Arizona; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

²Weaver, John E., and Clements, Frederic E. *Plant ecology*. Ed. 2, 601 pp. New York: McGraw-Hill Co. 1938.

Figure 1.--Typical vegetation near study area: background, velvet mesquite; foreground, burroweed.



Soil Temperature Measurements

Soil temperatures were derived from thermistors in Colman soil moisture units buried in the soil at 3, 12, and 24 inches. Each depth was replicated 14 times. Readings were taken daily (within about 2 hours after sunrise) during periods of vegetation growth, and weekly at other times from July 1961 to October 1963. Starting on December 14, 1961, and continuing at intervals of about 2 months for 1 year, readings at 2-hour intervals from 6 a.m. to 10 p.m. were taken also from another series of seven units buried at depths of 0.5, 1, 2, 3, 6, 12, and 24 inches. Air temperatures were measured in the shade 0.5 inch above the ground surface. Weekly mean maximum and minimum air temperatures were also measured in a U. S. Weather Bureau shelter at the Santa Rita headquarters, 3 miles from the study area.

Results

Daily and Seasonal Fluctuations

Soil temperatures fluctuated daily in response to changes in air temperatures. Minimums at all depths down to 6 inches were recorded just before sunrise (fig. 2). The minimum at 12 inches was usually reached at noon, and daily fluctuations at 24 inches were very limited and apparently inconsistent. At 6 a.m., the 0.5-inch depth was the coldest on all dates, and the 24-inch depth the warmest (except on June 21). Rapid surface heating during the morning reversed this pattern, leaving the lowest temperatures at 12 and 24 inches and the highest temperature at the 0.5-inch depth. With the rapid cooling in late afternoon, the pattern reversed again. Thus, at all seasons the typical daily minimum and maximum were recorded at the soil surface, and daily temperature extremes decreased with depth. The absolute maximum and minimum soil temperatures recorded in the study were 141°F. and 29°F. Maximum and minimum soil temperatures reported by Shreve³ for depths of 3 and 12 inches, measured under somewhat similar climatic conditions near Tucson, are roughly comparable to those reported in this study.

³Shreve, Forrest. *Physical conditions in sun and shade. Ecology* 12: 96-104. 1931.

Soil temperatures on sunny days varied less among the seven depths at 6 a.m. than at 2 p.m. Also, variations among depths were greater in summer than winter. For example, at 2 p.m. on the one sunny winter day sampled (February 15), the highest soil temperature measured was 84°F. at 0.5-inch depth, and the temperature varied 29° among depths. At 2 p.m. on the hottest summer day sampled (June 21), the highest soil temperature measured was 141°F. at 0.5-inch depth (air temperature, 109°F.), and the temperature varied 60° among depths. Just as the surface soil absorbs heat rapidly from sunrise until midafternoon, it also loses heat rapidly in the late afternoon as the sun approaches the horizon and air temperatures decline.

Diurnal temperature extremes were greatest on sunny summer days. For example, at 0.5 inch the spread between maximum and minimum on an overcast day (December 14, 1961) was 10°F.; on a sunny winter day (February 15, 1962) the spread was 40°F.; but on a sunny summer day (June 21, 1962) the spread was 75°F. The insulating effect of soil is apparent in the greatly reduced diurnal temperature extremes (only 2° spread) at 24 inches on the same summer day (table 1).

December 14, 1961, was unusual (for the Southwest) in that the sky was overcast all day, with several intermittent light showers. As a result, the normal daytime rise in temperatures was largely suppressed (fig. 2).

Temperature Lag

Daily and seasonal maximum soil temperatures usually occur sometime after maximum air temperatures are recorded. Maximum daily soil temperatures at the 0.5-, 1-, and 2-inch depths were recorded at 2 p.m., as were maximum air temperatures (time lags shorter than 2 hours were not measured). Maximum temperatures at the 3-, 6-, and 12-inch depths were recorded at 4, 6, and 8 to 10 p.m., respectively. The 24-inch depth exhibited no well-defined time lag, but morning temperatures generally averaged higher than afternoon temperatures, indicating a probably time lag of 12 to 18 hours.

Minimum daily temperatures within the surface 6 inches of soil coincided with minimum air temperatures, and were recorded just before sunrise. At 12 inches the minimum was usually recorded about noon, but diurnal variation at 24 inches was too small to show a consistent minimum.

Table 1.--Air temperatures¹ and soil temperature characteristics at seven depths in summer and winter

Weather conditions and date	Air temperatures	Soil temperatures by depths in inches							
		0.5	1	2	3	6	12	24	Range
-----°F.-----									
SUMMER (DRY, SUNNY)									
June 21, 1961									
Maximum	110	² 141	134	122	113	100	89	83	58
Minimum	66	66	68	73	79	82	82	81	16
Range	44	75	66	49	34	18	7	2	
WINTER (DRY, SUNNY)									
February 15, 1962									
Maximum	75	84	81	75	73	68	60	57	17
Minimum	41	44	44	46	49	52	54	56	12
Range	34	40	37	29	24	16	6	1	
WINTER (OVERCAST, WITH OCCASIONAL LIGHT RAIN)									
December 14, 1961									
Maximum	52	51	50	49	50	49	52	55	6
Minimum	40	41	41	41	44	46	50	54	13
Range	12	10	9	8	6	3	2	1	

¹ Measured in shade 0.5 inch above the ground surface.

² Highest soil temperature recorded during study period.

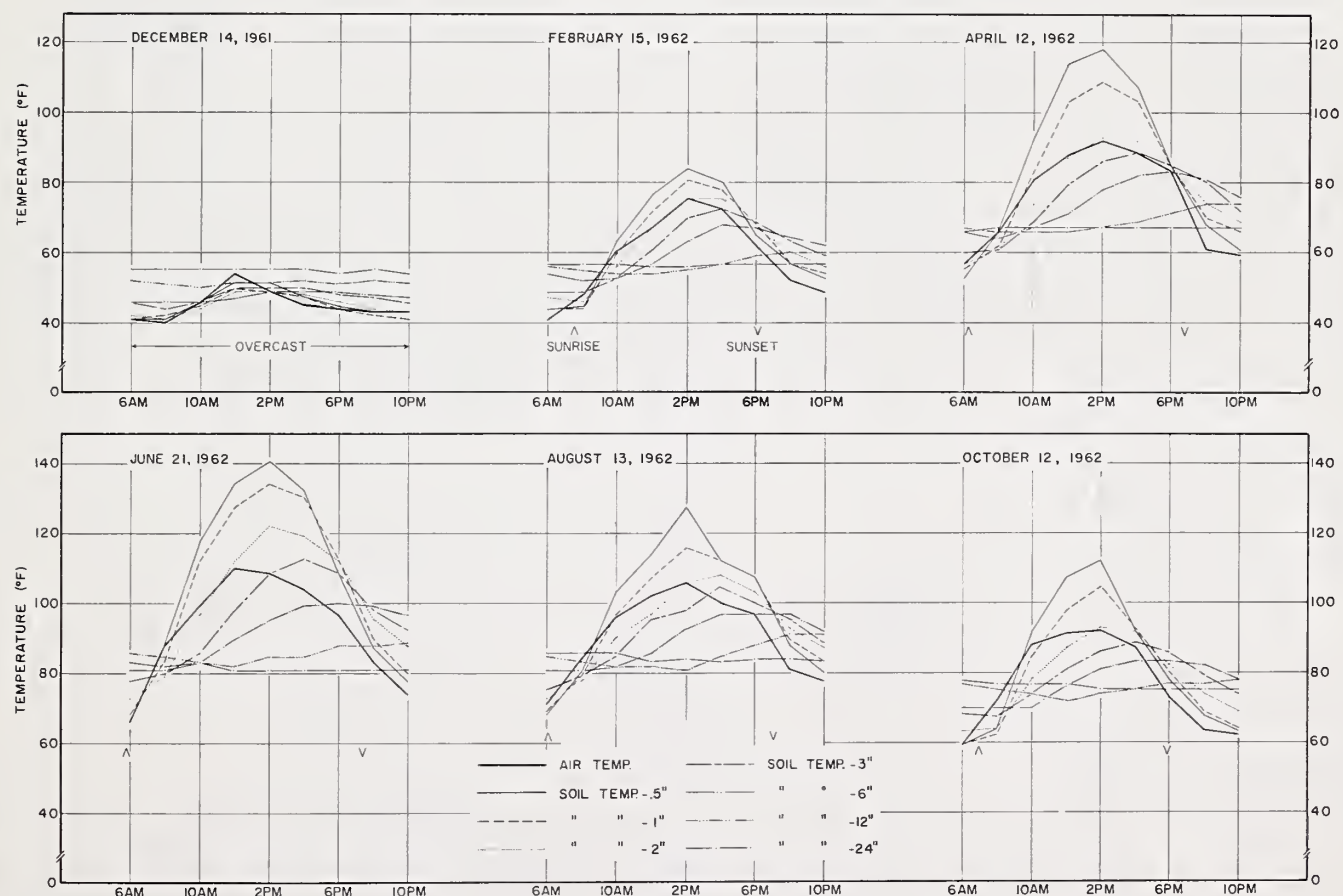


Figure 2.--Air temperature and soil temperatures at 7 depths, from 6 a.m. to 10 p.m. on 6 days from December 14, 1961 to October 12, 1962.

Seasonally, maximum insolation is received on June 21, and minimum insolation on December 21. But, seasonal minimum soil temperatures were reached about the middle of January, and seasonal maximums between mid-July and mid-August (fig. 3). Soil temperatures were well correlated with and usually fell within the range between weekly mean maximum and minimum air temperatures at the Santa Rita headquarters.

Summary

The data presented on soil temperature characteristics on semidesert rangeland in southern Arizona indicate:

1. Soil temperature varied in response to variations in atmospheric temperature and insolation, generally reaching a minimum just before sunrise and a maximum at about 2 p.m.
2. Daily minimum soil temperatures were lowest at the surface and increased with depth; daily maximum soil temperatures were highest at the surface and decreased with depth. The difference between the daily maximum and minimum soil temperatures

- at a given depth decreased rapidly with depth from as much as 75° at the surface to only 1° or 2° at the 24-inch depth.
3. The temperature in the top inch of soil rose as much as 32° higher than that of the air 0.5 inch above the soil surface.
4. Diurnal soil temperature changes on an overcast winter day were much smaller than on the usual sunny day because of restricted daytime soil heating.
5. Maximum soil temperatures at depths below 2 inches lagged increasingly behind those at the surface until at 24 inches the lag was 12 to 18 hours. Minimum soil temperatures lagged behind air temperature only at 12 and 24 inches.
6. Seasonal maximum and minimum soil temperatures were reached between mid-July and mid-August, and in mid-January, respectively.
7. Soil temperatures at the 3-, 12-, and 24-inch depths ranged mostly between 40° and 60°F. during the winter months, and between 70° and 90°F. during the summer months. Absolute maximum and minimum temperatures recorded during the study period were 141° and 29°F.

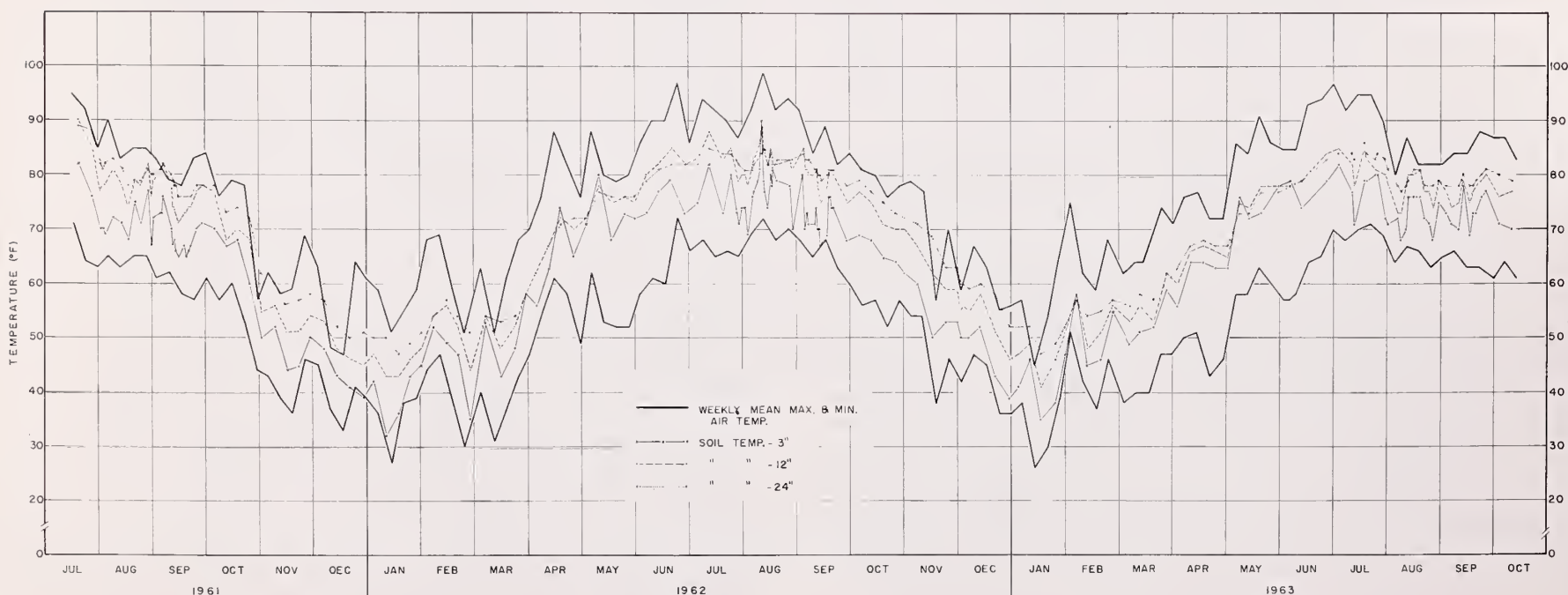


Figure 3.--Weekly mean maximum and minimum air temperatures, and soil temperatures at 3, 12, and 24 inches, measured within 2 hours after sunrise from July 1961 to October 1963.